BORAX AS A DISINFECTANT FOR CITRUS FRUITS

BY

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BORAX AS A DISINFECTANT FOR CITRUS FRUIT [1]

By WILLIAM R. BARGER, *Assistant Physiologist*, and LON A. HAWKINS, *Physiologist, Horticultural Investigations, Bureau of Plant Industry, United States Department of Agriculture*

The use of disinfectants in washing citrus fruits has been a common practice in California for many years. In 1906 Smith [2] showed that the brown-rot of lemons caused by *Pythiacystis citrophthora* Smith and Smith, could be controlled by a solution of potassium permanganate, copper sulphate, or formalin in the wash water. Since then copper sulphate has been used to a considerable extent commercially. For fifteen or twenty years hot water and soap have been employed in washing both oranges and lemons, and for the past ten years a soap containing borax has been extensively used. It has also been a common practice in some packing houses to use a dilute solution of borax in the wash water in addition to the soap. Except in the case of brown-rot of lemons, there appears to be no data on the exact effect of these various disinfectants in the control of the fungous diseases of Citrus which gain entrance to the fruit in handling and harvesting operations and are particularly evident during transit and on the market.[3] To obtain more exact information upon the possibilities of controlling some of the common Citrus parasites such as blue mold, caused by *Penicillium italicum* Wehmer, and green mold, caused by *Penicillium digitatum* Sacc., a series of experiments was conducted in which some common and cheap disinfectants were used in the wash water. Since the results of these investigations were fairly definite and present a basis for further commercial application of disinfectants in the control of certain Citrus diseases, a preliminary presentation is here given.

The work was begun in California early in 1924, either Navel or Valencia oranges being used in all experiments described in this paper. In the first preliminary experiment, powdered boric acid U. S. P. and potassium alum Tech. were used. Navel oranges, which had been picked from four to six weeks, were prepared for the experiment by removing thin slices of skin from each fruit. Seventy-five fruits were immersed for five minutes in a solution of 2.5 per cent of boric acid at a temperature of 120° F.; two other lots of 75 each were treated, one by immersing in a solution of 4.5 per cent powdered alum and the other in hot water only for five minutes at 120° F. After the fruits had been removed from the baths they were inoculated with spores of blue mold obtained from a decayed fruit. The fruit was dried, packed, and stored in a room having a temperature of about 70° F. and a humidity of about 90 per cent. After one week both the fruit treated with hot water and that treated with powdered alum solution showed 100 per cent decay caused by blue mold. The lot treated with boric acid showed only 2.5 per cent decay from blue mold and about the same percentage from green mold. Further holding of the lot showed some decay from what seemed to be *Alternaria* sp. or *Pythiacystis* sp. In this connection it is interesting to note that Smith [4] found that very dilute solutions of boric acid would not control *Pythiacystis citrophtora* on lemons.

This experiment indicated that boric acid offered very promising possibilities and that alum was apparently of no particular value in concentrations such as could safely be used in washing the fruit. Borax (technical grade) was later tested and found to be as effective as boric acid in controlling blue-mold decay, and, being much cheaper, was used in all later experiments. The investigation here described was concerned mainly with testing the efficiency of a 2.5 per cent solution of borax at various temperatures and with different methods of application in the control of blue and green mold which had been inoculated

[1] Received for publication Aug. 31, 1924; issued April, 1925.

[2] SMITH, R. E., and others. THE BROWN-ROT OF THE LEMON. Calif. Agr. Exp. Sta. Bul. 190, 72 p., illus. 1907.

[3] POWELL, G. H., and others. THE DECAY OF ORANGES WHILE IN TRANSIT FROM CALIFORNIA. U. S. Dept. Agr., Bur. Plant Indus. Bul. 123, 79 p., illus. 1908.

[4] SMITH, R. E. OP. CIT.

on the surface of wounded fruit and in punctures similar to those made by stem or thorns.

The fruit was prepared for inoculation either by cutting thin slices of the rind just below the oil cells and into the white portion similar to the wound made by a clipper cut or by puncturing the rind with a knife to the depth of about 2 mm. The depth the knife was thrust into the fruit was controlled by wrapping tire tape around the blade so that it could penetrate the fruit only to the depth required. The inoculations were made by rubbing spores on the cut surface, where a portion of the rind was sliced away, and by dipping the knife in a mass of spores when making the wound by puncture. The spores for inoculating the fruit were obtained from decayed oranges. Since the greater part of this work was done under ordinary packing-house conditions and with the regular packing-house machinery, no attempt was made to get pure cultures of the fungi for making inoculations. Decayed oranges were selected, however, as the source of spores, because judging from the external character and color (*1*, *3*), these seemed to furnish practically pure cultures of the fungi.[5] In many cases, undoubtedly, the fruit was inoculated from mixed cultures and there was especially in the controls considerable possibility of natural inoculations when the regular packing-house machinery was used in handling the fruit.

In the early experiments the procedure was to wound the fruit, treat it with a 2.5 per cent solution of borax, either by immersing or floating it in this solution, inoculating it by rubbing a finger dipped in the blue mold spores on the cut surface, drying in the air, wrapping, packing, and storing. The fruit was usually stored at about 70° F. with a humidity of about 90 per cent. Controls were prepared in exactly the same way except that instead of being treated with the borax solution they were treated with water only and inoculated with the fungi. At the end of one week the fruit was examined, the decayed fruits classified and removed, and the remaining sound fruits allowed to remain for the next inspection. When the fruit was immersed, it was held about 4 inches below the surface of the solution by a rack. When it was floated no weight was used, and it was allowed to float freely in the tank of solution, from one-eighth to one-tenth of the rind being exposed above the surface. The results of the experiments made with blue mold fungus on Valencia oranges are shown in Table I.

Table I shows that there is much more decay in the untreated fruit after one week than in any of the borax-treated lots. In the latter the best results were obtained at the higher temperatures and when the fruit was allowed to remain for four minutes or more in the solution. In no case was there more than 4.5 per cent of blue mold in any of the lots treated at 120° F. except in the two lots sprayed with water after being treated with the borax solution. In these lots the decay caused by blue mold after one week was 6.1 and 7.8 per cent. Evidently for the best results the borax solution should be allowed to dry on the fruit. At the higher temperatures blue mold is apparently controlled as well by allowing the fruit to float in the borax solution as by immersing it. At the lower temperatures, however, floating did not give as good results as did immersion. In the lots of fruit injured by puncturing and inoculating in these wounds, practically as good control was obtained as when the wounds were superficial.

The results of the inspections after two weeks show some increase in the amount of blue mold present in the treated fruit, although in the lots treated at 120° for eight minutes there was in no case more than 5 per cent of blue mold decay. There was little increase in blue mold decay after five to seven weeks. The amount of decay caused by green mold was very much higher during the later inspections than at the first. This fungus is apparently not so easily controlled by borax as is the blue mold fungus. Results of a series of experiments on the treatment of Valencia oranges inoculated with green mold are shown in Table II. The spores for inoculating this fruit were obtained from decayed specimens which appeared to be affected only with green mold, although, of course, as in the case of blue mold there was probably some contamination.

An inspection of Table II corroborates the observation indicated by Table I, namely, that green mold is not readily controlled by treatment with this concentration of borax. In the lots of fruit wounded on the surface and immersed, there was no apparent infec-

[5] THOM, C. CULTURAL STUDIES OF SPECIES OF PENICILLIUM. U. S. Dept. Agr., Bur. Anim. Indus. Bul. 118, 109 p., illus. 1910.

TABLE I.—*Showing percentage of decay in Valencia oranges, wounded on surface or punctured, immersed or floated in a 2. 5 per cent solution of borax, inoculated on the wounds with blue-mold spores, and held in a warm room at high humidity*

Treatment	Temperature bath	Time	Number of fruit	Percentage of decay after— One week		Two weeks		Five weeks		Seven weeks	
				Blue mold	Green mold	Blue mold	Green mold	Blue mold	Green mold	Blue mold	Green mold
	° F.	*Minutes*									
Control wounded and inoculated but not treated with borax			73	98. 6	0						
			100	100. 0							
			513	90. 0							
			686			92. 4	0				
			100	100. 0							
Wounded on surface, immersed in borax solution and inoculated	73	4	100	13. 0	17. 0	14. 0	65. 0	14. 0	84. 0		
	73	8	13	0	0	0	15. 3				
	120	3	224	4. 4	2. 6						
	120	3	459			9. 3	32. 4				
	120	3	224	4. 5	0						
	120	4	75	2. 6	2. 6						
	120	4	15	0	6. 6						
	120	4	395	2. 2	1. 2						
	120	4	972			12. 7	36. 0				
	120	4	485	2. 3	0						
Wounded on surface, floated in borax solution and inoculated	73	4	100	41. 0	16. 0	42. 0	48. 0	42. 0	54. 0		
	120	8	423	0	0						
	120	8	488			4. 9	25. 8				
Wounded on surface, immersed in borax solution, inoculated, and rinsed with water	73	4	50	26. 0	16. 0	26. 0	38. 0	26. 0	60. 0		
	73	6	50	60. 0	8. 0	64. 0	24. 0	64. 0	36. 0		
Wounded on surface, immersed in borax solution, inoculated and sprayed with water	120	6	587	6. 1	6. 8						
	120	6	701	7. 8		45. 1	30. 1				
Control punctured and inoculated; not treated with borax			250	83. 6	0	84. 8	0	86. 0	0		
Wounded by puncturing, inoculated and immersed in borax solution	70	8	50	0	0	2. 0	0	2. 0	4. 0	2. 0	4. 0
	120	4	100	2. 0	0	6. 0	4. 0	6. 0	46. 0	7. 0	53. 0
	120	6	100	0	0	2. 0	3. 0	2. 0	34. 0	3. 0	40. 0
	120	8	150	3. 3	0. 6	4. 6	2. 6	5. 3	30. 0	5. 3	37. 9

TABLE II.—*Showing percentage of decay in Valencia oranges, wounded on surface or punctured: immersed or floated in a 2.5 per cent solution of borax, inoculated with green mold spores, and held in a warm room at high humidity*

Treatment	Temperature bath	Time	Number of fruit	Percentage of decay after— One week		Two weeks		Five weeks		Seven weeks	
				Blue mold	Green mold	Blue mold	Green mold	Blue mold	Green mold	Blue mold	Green mold
Control wounded on surface and inoculated, not treated with borax	° F.	*Minutes*	100	80. 0	20. 0						
Wounded on surface and immersed in borax solution	67	4	100	0	27. 0	0	97. 0	0	99. 0		
	67	8	100	0	15. 0	0	92. 0	0	95. 0		
	120	4	100	0	24. 0	0	92. 0	0	98. 0		
	120	8	100	0	2. 0	0	50. 0	0	73. 0	0	80. 0
Control wounded by puncturing, inoculated, not treated with borax			37	0	100. 0						
Wounded by puncturing, inoculated and immersed in borax solution	73	4	100	11. 0	2. 0	15. 0	2. 0	18. 0	24. 0	19. 0	28. 0
	73	6	100	16. 0	0	18. 0	7. 0	21. 0	45. 0	22. 0	50. 0
	70	8	46	0	8. 7	0	48. 0	0	84. 8		
Same except treated by floating in borax solution	73	4	50	8. 0	0	8. 0	4. 0	10. 0	42. 0	10. 0	44. 0
	73	6	50	14. 0	0	18. 0	4. 0	18. 0	26. 0	18. 0	32. 0

tion from blue mold but at the end of five weeks 73 per cent or more of the fruit had decayed from what apparently was green mold. With the fruit inoculated by puncturing and immersion, the results are not so striking; there is considerably more blue mold present, indicating contamination of the culture used for inoculation. The percentage of rot caused by green mold as shown by the later inspections is high in all cases, although it was above 50 per cent in only one case.

From the results of the experiments herein reported it is evident that blue mold rot, which causes so much damage to Citrus fruit in California, can be largely controlled by treating the fruit with a solution of borax. Much of the work described in this paper was done in the packing house and with equipment suitable for application in a commercial way. It remains, however, to make further experiments on a commercial basis, to determine the value of the treatment in actual shipping and marketing tests. While borax [6] in the concentration used is not so effective in the control of green mold as in that of blue mold, it is probable that higher concentrations of borax or other disinfectants may be found which will be effectious against this fungus. Work along these lines is in progress.

[6] The question as to whether treatment with borax should be indicated by special label or otherwise for interstate shipment has not yet been determined.

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